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M. J. Bearden 2-4-2-2

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PATENT APPLICATION

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CASE: 2-4-2-2

TITLE: METHOD AND APPARATUS FOR USE IN SPECIFYING AND INSURING SERVICE-LEVEL QUALITY OF SERVICE IN COMPUTER NETWORKS

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

SIR:
Enclosed are the following papers relating to the above-named application for patent:
  16 Page specification and Claims
   3 Sheets of Informal drawings
      Unexecuted Declaration and Power of Attorney
      Information Disclosure Statement and Documents

CLAIMS AS FILED
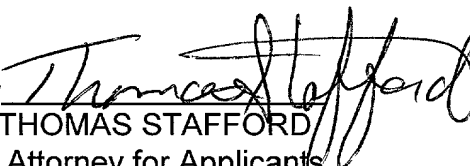
	No. Filed	No. Extra	Rate	Calculations
Total Claims	42-20 =	22	x $18 =	396
Independent Claims	4 - 3 =	1	x $78 =	78
Multiple Dependent Claim(s), if applicable	0		$270 =	0
Basic Fee				690
			TOTAL FEE	**1164**

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Please file the application and charge **Lucent Technologies Deposit Account No. 12-2325** the above-indicated amount, to cover the filing fee. Duplicate copies of this letter are enclosed. In the event of non-payment or improper payment of a required fee, the Commissioner is authorized to charge or to credit Deposit Account No.12-2325 as required to correct the error.

Please address all correspondence to **Thomas Stafford, 4173 Rotherham Court, Palm Harbor, Florida 34685**. Telephone calls should be made to Thomas Stafford at 727-772-4173 and FAX calls at 727-772-2545.

Respectfully,
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METHOD AND APPARATUS FOR USE IN SPECIFYING AND INSURING SERVICE-LEVEL QUALITY OF SERVICE IN COMPUTER NETWORKS

Related Application

5   United States patent application Serial No. (M. J. Bearden-S. Garg-W. Lee-A. P. A. van Moorsel Case 3-5-3-3) was filed concurrently herewith.

Technical Field

This invention relates to computer networks and, more particularly, to monitoring and controlling quality of service (QoS) in such computer networks.

10 Background of the Invention

Known policy-based computer network management arrangements do not clearly distinguish the goal, i.e. the "what", of management from the policy, i.e. the "how", that achieves the goal. Indeed, most known policy-based management (PBM) arrangements require a system administrator to specify policies as declarative rules of the form "if

15 event/condition then action." From a system administrator's viewpoint, such rules represent a "high-level" specification of "what" needs to be achieved in terms of the network/system behavior. However, from the viewpoint of a client, i.e. the end user of a service, such rules represent a "low-level" specification of "how" the client's desired system behavior is to be achieved. This makes it difficult or impossible for clients

20 without expertise in network management to express the desired system behavior in a way supported by known PBM arrangements. Instead, a system administrator typically translates the client's "high-level" description of the desired system behavior, i.e. service-level QoS goals, into "low-level" rule-based or procedural syntax of network management policies. To summarize, in the known PBM arrangements, there is no

25 support for specifying the client's service-level QoS goals as part of the network management policy definition.

Summary of the Invention

Problems and/or limitations of prior policy-based network management arrangements are addressed by integrating the "what" and "how" of PBM in a single

30 framework that enables a system administrator to specify service-level QoS goals for automatic enforcement instead of, or in addition to, policy rules or procedures.

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Automatic enforcement of the specified QoS goals is realized through the execution of policy logic, i.e. policy rules or procedures, without the client or system administrator having to specify the policy logic in the form of rules and/or procedures.

Specifically, one embodiment of the invention employs a management server including a graphical interface that allows a user, e.g. an administrator, to easily specify parameters for predefined types of service-level QoS goals. A QoS goal is defined by specifying a client, a service, and a QoS expression. A QoS expression is a proposition that indicates the client's desired range of values for some QoS metric, e.g. service response time or service availability. The state of the network is monitored and one or more defined QoS goals are selected for evaluation in a continuous process. The QoS delivered for the selected goal is determined and compared to the selected QoS goal. Then, prescribed actions are taken or not depending whether the delivered QoS is equal to the selected QoS goal. If not, and the delivered QoS exceeds the selected QoS goal, a set of actions is determined and executed to reduce network resources, i.e. network element resources, assigned to the client and service of the selected goal. Similarly, if the delivered QoS is worse than the selected QoS goal, a set of actions is determined and executed to increase network resources assigned to the client and service of the selected goal.

In an embodiment of the invention, QoS goals are stored in a goal repository and continuously updated by adding, redefining, or removing a service-level QoS goal as requested by an administrator.

Similarly, in an embodiment of the invention, the state of the network is monitored and the results are stored in a monitored state repository. Also stored in the monitored state repository are state changes indicated by received network event notifications.

Brief Description of the Drawing

FIG. 1 is a table illustrating in simplified and generalized form example "high-level" QoS management goals;

FIG. 2 is a table illustrating in simplified form an example policy procedural logic;

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FIG. 3 shows, in simplified form, details of a network employing an embodiment of the invention; and

FIG. 4 is a flow chart illustrating steps in a process employed in an embodiment of the invention.

Detailed Description

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Again, it is noted that current PBM arrangements require system administrators to specify rules that to the system administrator represent the specification of "what" needs to be achieved in terms of network/system behavior. From a client viewpoint, however, these rules represent the "how" of management. The client is really interested in service-

10 level QoS goals such as "my transaction failure rate should be less than some specific value" or "my end-to-end response should be less than some specific value". Indeed, there is currently no support in prior arrangements for specifying the client's service-level QoS goals as part of the management policy definition.

FIG. 1 is a table illustrating in simplified form example QoS goals. As shown,

15 QoS goals are represented using the generalized goal template shown in TABLE 1, namely, "during T, satisfy Q for client C that uses service S". The goal parameters, in this example, are defined as follows. Parameters C and S identify respectively a client and some service accessed by the client, such as a Web or DNS server, a networked application server, or a file server. Parameter Q is a QoS expression with three parts, as

20 follows. The first part is Q.metric that identifies a QoS metric such as end-to-end service delay, transaction failure rate, etc.; the second part is Q.op, an operator used to compute whether the client's delivered QoS value satisfies the desired QoS; the third part is Q.value, a value that represents the desired QoS for the given QoS metric. The QoS expression will evaluate to "true" or "false" at run time when the given operator Q.op is

25 used to compare the delivered QoS for the given metric to the desired QoS, Q.value. Finally, parameter T identifies a time range when the given QoS goal is intended to have effect. By way of an example, consider an end-to-end QoS goal as follows: "Provide client Joe with average SAP transaction delay of at most 1 second," where SAP is an example networked service. This QoS goal is represented by setting the parameters of

30 TABLE 1 as follows: C = "Joe", S = "SAP", Q.metric = "AvgSAPTransactResponse", Q.op = "≤", Q.value = "1 second", and T = "Always". The goal is satisfied when client

Joe's average SAP transaction response time is determined, through observation and/or estimation, to be less than or equal to one second. The goal is not satisfied whenever Joe's SAP average transaction response time is determined to be greater than one second.

FIG. 2 is a table illustrating in simplified form an example policy procedural logic. Specifically, shown in TABLE 2 is pseudocode for one possible (simplistic) procedure for enforcing the above QoS goal in a networked system with priority-based packet switching and a function defined as getClientQoS() that measures or computes a client's transaction delay. The example pseudocode is explained as follows. The "if" condition in line 1 is satisfied when the delivered QoS for client C using service S does not satisfy the QoS expression of the goal specified for client C and service S. Line 3 specifies an example action that is expected to help the delivered QoS for client C to achieve the value specified in the goal. Specifically, in this example the priority for network traffic is increased, for traffic generated by client C accessing service S. Lines 5 through 10 specify a rule of the form "if condition then action" similar to those commonly supported by existing PBM arrangements and by existing QoS-enabled network devices. In lines 5 through 7, the condition part of the rule identifies that a given packet P is part of client C's communication with service S. Line 9 contains the action part of the rule, which in the given example is setting the appropriate priority for switching and queuing the packet at network elements. Line 4 indicates that this policy rule should be enforced at each element in the network over which client C accesses service S.

It is noted that such a procedure can be specified by a management expert in advance and reused for a number of different goal parameters, i.e. for different clients, services, QoS metrics, etc. Indeed, the procedural policy specification is highly dependent on the types of parameters assigned to the QoS goal template, and on the types of elements in the networked system that can be controlled in order to enforce QoS.

It is felt best to consider some terminology. Thus, a "policy" is defined to be a process that implements a function with a parameter called an "objective." An "objective" is defined to be a Boolean expression over some set of goals. A goal is a proposition defined as above on (1) a "service", i.e. an application, (2) a "client" that accesses the service, (3) a "time range" for goal enforcement, and (4) a "QoS

"expression" specified using applicable metric identifiers, operators, and values. Again, an example goal proposition is as follows: Client = Joe, Service = SAP, Time = Always and TransactionDelay ≤ 1 ms. A "policy instance" P(H) exists whenever objective H is enforced using policy P. The inputs to a policy instance are state updates of the client,

5 service, and network elements that allow the client to access the service, and its outputs are a combination of (1) policy rules consumed by rule-based PBM software, (2) control signals sent to network elements and resources to affect the client's QoS, and/or (3) notifications sent to a administrative interface, including but not limited to service-level alarms and suggested manual network provisioning actions.

10 An embodiment of the invention allows the user (system administrator) to specify a set of goals and objectives in a goal repository, describing the "what" of the service-level QoS management. For each goal G in some objective H specified, a policy is automatically selected such that the effect of executing P(G) is to enforce goal G to the extent that is feasible given the available networked resources. Thus, the invention

15 accepts only a limited set of goals for which the embodiment of the invention contains the policy logic needed to enforce those goals. The "how" of enforcing the goals is specified by the policy logic contained in the invention's embodiment. As noted earlier, a simplified example of policy logic is given in TABLE 2 of FIG. 2.

In this embodiment of the invention there is an explicit distinction between the

20 "what" and "how" of PBM and each one is an integral part of a policy framework and a PBM solution which enables the following:

- Directly specifying (and modifying on-line) clients' service-level QoS goals as part of the network management objective;

- Easily reporting and verifying the effectiveness of policy-based management

25 for achieving these goals;

- Providing feedback so that policy logic can be modified, either manually off-line or automatically on-line to achieve desired QoS goals;

- Enabling service providers and clients to establish service-level agreements (SLA's) based on goals and objectives that are mutually understood. As an

30 integral part of the policy specification, such SLA's enable an SLA-based

revenue model for service providers, as opposed to the flat-rate pricing that is presently the norm for service providers.

FIG. 3 shows, in simplified form, details of network 300 employing an embodiment of the invention. Specifically, shown are management server 301 including an embodiment of the invention, an associated graphical user interface 302, goal repository 304, and monitored state repository 305. Management server 301 is controllably connected to a data communication network 306, for example, the internet or World Wide Web (the Web), that includes a set of one or more configurable QoS-enabled network elements 307-1 through 307-N. A set of service servers 308-1 through 308-X is also controllably connected to data communications network 306. Finally, a set of client stations 309-1 through 309-Y is also controllably connected to data communications network 306. It is noted that client stations 307 may each be a personal computer (PC), workstation or the like for accessing data communication network 306, i.e. the internet. In this example, configurable QoS-enabled network elements 307 may include network routers and switches, network traffic shapers, application-level traffic redirectors, and application-level or network-level load balancers; the service servers 308 may include file servers (e.g. NFS), database servers (e.g. SQL), naming servers (e.g. DNS), network directories (e.g. LDAP), enterprise resource planning software (e.g. SAP or PeopleSoft), or servers running any other networked application; and the clients 309 may include thin client terminals, personal digital assistants, telephony or video devices, or web browsers, applets, agents, or client programs running on personal computers or workstations .

FIG. 4 is a flow chart illustrating steps in a process employed in an embodiment of the invention. The process is started in step 401. At run time, a system administrator or the like employing user interface 302 defines a service level QoS goal by selecting a client from 309-1 through 309-Y, an application from service servers 308-1 through 308-X, and a QoS expression. Stated another way, user interface 302 allows the system administrator to specify goal parameters for an objective "H" and choose when attempted enforcement of "H" should begin. At that time management server 301 parameterizes and instantiates P(G) for each goal G that is part of objective H, such that the policy logic of P is appropriate for enforcing goal G. For example, the policy logic described in simplified form in FIG. 2 could be selected to enforce a goal of the form given in FIG. 1.

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Thereafter, in this example, three processes run concurrently in management server 301. Specifically, a first sub-process includes maintaining the goal repository 304, a second sub-process maintains the monitored state repository 305 and a third sub-process effects the QoS management of defined goals. Again, these three sub-processes, once started,

5   run concurrently and continuously.

The first sub-process of maintaining the goal repository 304 includes step 402 that causes the updating of goal repository 304 by adding, redefining or removing a service level QoS goal. Then, step 403 tests to determine whether the contents of goal repository 304 should be modified. If the test result in step 403 is YES, control is returned to step

10   402 that causes the updating of goal repository 304. If the test result in step 403 is NO, the test is iterated until a YES result is obtained and control is again returned to step 402. Steps 402 and 403 are continuously iterated, as described above.

The second sub-process of maintaining the monitored state repository 305 includes step 404 that tests to determine whether a network state update should be

15   requested now. The network update is realized by monitoring elements employed in the network, including both clients and service servers. In one example, the monitoring is realized by obtaining measures of service performance statistics. The desired measurements are collected, in one example, by employing a so-called VitalAgent client-side monitoring software commercially available from Lucent Technologies Inc. See for

20   example, http://www.ins.com/software/ for VitalAgent product documentation. If the test result in step 404 is YES, step 405 causes a query of the network element(s). Thereafter, step 407 tests to determine whether a network event notification has been received either for previously requested network state update or for an (unrequested) network update, i.e. an asynchronous or trap update. Such an event notification indicates that the state of the

25   network has changed by the event that has occurred. If the test result in step 407 is YES, then step 406 causes the updated state to be stored in monitored state repository 305. Otherwise, if the test result in step 407 is NO, the control is returned to step 404. Returning to step 404, if the test result is NO, no update is requested and control is passed to step 407. Appropriate ones of steps 404 through 407 are iterated continuously.

30   The third sub-process of effecting the desired QoS management of defined goals includes step 408 that sets a counter X equal to one (1). Then step 409 causes the

selection of the Xth defined QoS goal in goal repository 304. Step 410 causes the use of the contents of monitored state repository 305 to determine the delivered QoS for the selected goal. In step 411, the delivered QoS is compared with the QoS expression of the selected QoS goal. Then, step 412 tests to determine if the delivered QoS is equal to the

5 desired QoS for the selected QoS goal. If the test result in step 412 is YES, control is passed to step 413. Step 413 causes a report to be sent to the system administrator indicating that the delivered QoS satisfies the selected QoS goal. Then, step 414 causes counter X to be incremented by one (1), namely, $X = X+1$. Step 415 tests to determine if X in counter X is greater than the number of QoS goals in goal repository 304. If the test

10 result in step 415 is YES, control is returned to step 408 and steps 408 through 415 are iterated until either step 412 or step 415 yields a NO result. If step 415 yields a NO result, control is returned to step 409 and steps 409 though 415 are iterated until step 412 yields a no result or step 415 yields a YES result. If step 412 yields a NO result, control is passed to step 416. Step 416 tests to determine whether the delivered QoS exceeds the

15 selected QoS goal. If the test result in step 416 is YES, control is passed to step 417. Step 417 determines and executes a set of actions to reduce network resources, i.e. the resources of network elements such as buffer space or reserved bandwidth at a router, assigned to the client and service of the selected QoS goal. Thereafter, control is passed to step 413 that reports the set of actions taken in step 417, and the results of said actions,

20 to the system administrator. Returning to step 416, is the test result is NO, control is passed to step 418. Step 418 determines and executes a set of actions to increase the amount of network resources assigned to the client and service of the selected QoS goal. Thereafter, control is passed to step 413 that reports the set of actions taken in step 417, and the results of said actions, to the system administrator. Then, control is passed to

25 step 414 that increments counter X by one (1). Thereafter, step 415 is repeated as described above, and appropriate ones of steps 408 through 418 are iterated continuously. It is noted that the computations performed in the control flow, especially in steps 404, 410, 417 and 418, must vary depending upon the type of parameters included in the enforced goals and with the types of elements in the networked system wherein the QoS

30 goals are enforced.

The above-described embodiments are, of course, merely illustrative of the principles of the invention. Indeed, numerous other methods or apparatus may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1   1. A method for use in a policy-based management system comprising the steps
2   of:

3   selecting a prescribed quality of service goal for a prescribed client and prescribed
4   service;

5   determining a delivered quality of service for said selected quality of service goal;

6   determining if said delivered quality of service is different than said selected
7   quality of service goal; and

8   if so, executing prescribed actions regarding network resources assigned to said
9   client for said service, wherein said actions are intended to adjust said delivered quality
10   of service toward being equal to said selected quality of service goal.

1   2. The method as defined in claim 1 wherein a system administrator specifies
2   said quality of service goal without said system administrator having to specify said
3   prescribed actions intended to enforce said quality of service goal.

1   3. The method as defined in claim 2 wherein said quality of service goal is a
2   service level quality of service goal.

1   4. The method as defined in claim 3 wherein said step of determining said
2   delivered quality of service includes a step of employing monitored states of network
3   resources assigned to said client and said service to determine said delivered quality of
4   service.

1   5. The method as defined in claim 3 wherein said step of determining if said
2   delivered quality of service is different includes a step of determining if said delivered
3   quality of service exceeds said selected quality of service goal and, if so, said step of
4   executing includes steps of determining and executing a set of actions to reduce network
5   resources assigned to said client and said service of said selected quality of service goal.

1   6. The method as defined in claim 5 further including a step of reporting to said
2   system administrator said set of actions.

1   7. The method as defined in claim 5 further including a step of reporting to said
2   system administrator results of executing said actions.

1   8. The method as defined in claim 3 wherein said step of determining if said
2   delivered quality of service is different includes a step of determining if said delivered

3 quality of service is worse than said selected quality of service goal and, if so, said step of

4 executing includes steps of determining and executing a set of actions to increase

5 network resources assigned to said client and said service of said selected quality of

6 service goal.

1 　　　9. The method as defined in claim 8 further including a step of reporting to said

2 system administrator said set of actions.

1 　　　10. The method as defined in claim 9 further including a step of reporting to said

2 system administrator results of executing said actions.

1 　　　11. The method as defined in claim 1 further including the steps of storing said

2 selected quality of service goals and determining whether said stored quality of service

3 goals should be updated.

1 　　　12. The method as defined in claim 11 further including a step of updating said

2 stored quality of service goals.

1 　　　13. The method as defined in claim 12 wherein each of said quality of service

2 goals is a service level quality of service goal.

1 　　　14. The method as defined in claim 13 wherein said step of updating includes

2 steps of adding a service level quality of service goal to said stored quality of service

3 goals, redefining a stored service level quality of service goal or removing a stored

4 service level quality of service goal.

1 　　　15. The method as defined in claim 1 further including steps of monitoring a state

2 of each network resource in a set of network resources and storing said monitored states.

1 　　　16. The method as defined in claim 15 further including a step of updating said

2 monitored state of each network resource in said set of said network resources.

1 　　　17. The method as defined in claim 16 wherein said step of updating includes

2 steps of requesting an update of said state of each network resource in said set of network

3 resources, querying said state of each network resource in said set of network resources

4 and storing said updated state.

1 　　　18. The method as defined in claim 15 wherein said step of monitoring further

2 includes steps of receiving a network event notification indicating a change in state of a

3 network resource and storing said indicated change of state of said network resource as

4 an update of the state of said network resource.

1   19. A method for use in a policy-based management system comprising the steps

2 of:

3   storing a set of service level quality of service goals;

4   storing monitored states of a set of network resources;

5   selecting a prescribed defined quality of service goal from said stored service

6 level quality of service goals for a prescribed client and prescribed service;

7   using said stored monitored states to determine a delivered quality of service for

8 said selected quality of service goal;

9   determining if said delivered quality of service is different than said selected

10 quality of service goal; and

11   if so, executing prescribed action regarding network resources assigned to said

12 client for said service to adjust said delivered quality of service toward being equal to

13 said selected quality of service goal.

1   20. The method as defined in claim 19 wherein said step of determining if said

2 delivered quality of service is different includes a step of determining if said delivered

3 quality of service exceeds said selected quality of service goal and, if so, said step of

4 executing includes steps of determining and executing a set of actions to reduce network

5 resources assigned to said client and said service of said selected quality of service goal.

1   21. The method as defined in claim 20 further including a step of reporting to

2 said system administrator said set of actions.

1   22. The method as defined in claim 21 further including a step of reporting to

2 said system administrator results of executing said actions.

1   23. The method as defined in claim 19 wherein said step of determining if said

2 delivered quality of service is different includes a step of determining if said delivered

3 quality of service is worse than said selected quality of service goal and, if so, said step of

4 executing includes steps of determining and executing a set of actions to increase

5 network resources assigned to said client and said service of said selected quality of

6 service goal.

1   24. The method as defined in claim 23 further including a step of reporting to

2 said system administrator said set of actions.

1   25. The method as defined in claim 24 further including a step of reporting to
2 said system administrator results of executing said actions.

1   26. Apparatus for use in a policy-based management system comprising:

2   means for selecting a prescribed quality of service goal for a prescribed client and
3 prescribed service;

4   means for determining a delivered quality of service for said selected quality of
5 service goal;

6   means for determining if said delivered quality of service is different than said
7 selected quality of service goal; and

8   means, responsive to said delivered quality of service being different, for
9 executing prescribed actions regarding network resources assigned to said client for said
10 service, wherein said actions are intended to adjust said delivered quality of service
11 toward being equal to said selected quality of service goal.

1   27. The apparatus as defined in claim 26 wherein a system administrator specifies
2 said quality of service goal without said system administrator having to specify said
3 prescribed actions intended to enforce said quality of service goal.

1   28. The apparatus as defined in claim 27 wherein said quality of service goal is a
2 service level quality of service goal.

1   29. The apparatus as defined in claim 28 wherein said means for determining said
2 delivered quality of service includes means for employing monitored states of network
3 resources assigned to said client and said service to determine said delivered quality of
4 service.

1   30. The apparatus as defined in claim 28 wherein said means for determining if
2 said delivered quality of service is different includes means for determining if said
3 delivered quality of service exceeds said selected quality of service goal and means for
4 determining and executing a set of actions to reduce network resources assigned to said
5 client and said service of said selected quality of service goal.

1   31. The apparatus as defined in claim 30 further including a step of reporting to
2 said system administrator said set of actions.

1   32. The apparatus as defined in claim 30 further including a step of reporting to
2 said system administrator results of executing said actions.

1　　　33. The apparatus as defined in claim 28 wherein said means for determining if

2　said delivered quality of service is different includes means for determining if said

3　delivered quality of service is worse than said selected quality of service goal and means

4　for determining and executing a set of actions to increase network resources assigned to

5　said client and said service of said selected quality of service goal.

1　　　34. The apparatus as defined in claim 33 further including a step of reporting to

2　said system administrator said set of actions.

1　　　35. The apparatus as defined in claim 33 further including a step of reporting to

2　said system administrator results of executing said actions.

1　　　36. Apparatus for use in a policy-based management system comprising:

2　　　means for storing a set of service level quality of service goals;

3　　　means for storing monitored states of a set of network resources;

4　　　means for selecting a prescribed defined quality of service goal from said stored

5　service level quality of service goals for a prescribed client and prescribed service;

6　　　means for using said stored monitored states to determine a delivered quality of

7　service for said selected quality of service goal;

8　　　means for determining if said delivered quality of service is different than said

9　selected quality of service goal; and

10　　　means, responsive to said delivered quality of service being different, for

11　executing prescribed actions regarding network resources assigned to said client for said

12　service, wherein said actions are intended to adjust said delivered quality of service

13　toward being equal to said selected quality of service goal.

1　　　37. The apparatus as defined in claim 36 wherein said means for determining if

2　said delivered quality of service is different includes means for determining if said

3　delivered quality of service exceeds said selected quality of service goal and means for

4　determining and executing a set of actions to reduce network resources assigned to said

5　client and said service of said selected quality of service goal.

1　　　38. The apparatus as defined in claim 37 further including a step of reporting to

2　said system administrator said set of actions.

1　　　39. The apparatus as defined in claim 37 further including a step of reporting to

2　said system administrator results of executing said actions.

1   40. The apparatus as defined in claim 36 wherein said means for determining if
2   said delivered quality of service is different includes means for determining if said
3   delivered quality of service is worse than said selected quality of service goal and means
4   for determining and executing a set of actions to increase network resources assigned to
5   said client and said service of said selected quality of service goal.

1   41. The apparatus as defined in claim 40 further including a step of reporting to
2   said system administrator said set of actions.

1   42. The apparatus as defined in claim 40 further including a step of reporting to
2   said system administrator results of executing said actions.

Abstract of the Disclosure

The "what" and "how" of policy-based management is integrated in a single framework that enables a system administrator to specify service-level quality of service (QoS) goals for automatic enforcement. Automatic enforcement of the specified "high-level" QoS goals is realized through the execution of "low-level" rule-based or procedural logic, without the client having to specify the low level logic. Specifically, one embodiment of the invention employs a management server including a graphical interface that allows a user, e.g. a system administrator, to easily specify parameters for service-level QoS goals. A QoS goal is defined by the administrator selecting a client, a service and a QoS expression that specifies the desired service-level QoS. The state of the network is monitored and one or more defined QoS goals are selected for evaluation in a continuous process. The QoS delivered for the selected goal is determined and compared to the desired QoS for the selected QoS goal. Then, prescribed actions are taken or not depending whether the delivered QoS is equal to the selected QoS goal. If not, and the delivered QoS exceeds the selected QoS goal, a set of actions is determined and executed to reduce network resources assigned to the client and service of the selected goal. Similarly, if the delivered QoS is worse than the selected QoS goal, a set of actions is determined and executed to increase network resources assigned to the client and service of the selected goal.

FIG.1

TABLE 1

GOAL	GOAL PARAMETERS

DURING "T", SATISFY "Q" FOR CLIENT "C" USING SERVICE "S"	C: Client ε {client1, client2, ...}
	S: Service ε {Web, DNS, Fileserver, ERP, ...}
	Q: QoS Expression
	   Q.metric: QoS Metric ε {TransactionResponseTime, TransactionFailRate, ...}
	   Q.op: Operator ε {=, ≤, ≥, ...}
	   Q.value: Desired QoS Value ε {Float, Integer, Enumeration, ...}
	T: TimeRange

FIG.2

TABLE 2

PROCEDURAL POLICY LOGIC
1.   if (¬ satisfied (getClientQoS(C, Q.metric), Q.op, Q.value)) 2.   then 3.   set priority[C][S] = priority[C][S]++   // Make appropriate priority adjustment, i.e. increase. 4.   enforce the following "if condition then action" rule at each network element E that switches packets sent to/from C: 5.   if (packet P has arrived at E) && (timeOfDay is in T) && 6.   (((P.destIPport == S.serviceIPport) && (P.srcIPsubnet == C.subnetMask)) || 7.   ((P.srcIPport == S.serviceIPport) && (P.destIPsubnet == C.subnetMask))) 8.   then 9.   set P.priority = priority[C][S] 10.   endif 11. Endif

FIG. 3

Client
Station   309-Y

• • • •

Client
Station   309-1

Internet

Configurable
QoS-enabled
Network

307-1

302-N

300

306

Management
Server   301

USER
INTERFACE   302

300

GOAL
REPOSITORY   304

MONITORED
STATE
REPOSITORY   305

Service
Server   308-X

• • • •

Service
Server   308-1

START — 401

UPDATE GOAL REPOSITORY BY ADDING, REDEFINING, OR REMOVING A SERVICE LEVEL QoS GOAL — 402

MODIFY CONTENTS OF GOAL REPOSITORY? — 403
YES / NO

REQUEST NETWORK STATE UPDATE NOW? — 404
YES / NO

QUERY STATE OF NETWORK ELEMENT(S) — 405

RECEIVED NETWORK STATE OR EVENT NOTIFICATION? — 407
YES / NO

STORE UPDATED STATE IN MONITORED STATE REPOSITORY — 406

SET COUNTER X EQUAL TO 1 — 408

SELECT X^{th} DEFINED QoS GOAL IN GOAL REPOSITORY — 409

USING CONTENTS OF MONITORED STATE REPOSITORY, DETERMINE DELIVERED QoS FOR THE SELECTED GOAL — 410

COMPARE DELIVERED QoS TO THE SELECTED QoS GOAL — 411

IS DELIVERED QoS SAME AS DESIRED QoS IN SELECTED GOAL? — 412
YES / NO

IS X GREATER THAN NUMBER OF QoS GOALS IN GOAL REPOSITORY? — 415
NO / YES

INCREMENT COUNTER X BY 1 — 414

REPORT TO SYSTEM ADMINISTRATOR — 413

DOES DELIVERED QoS EXCEED DESIRED QoS IN SELECTED GOAL? — 416
NO / YES

DETERMINE AND EXECUTE SET OF ACTIONS TO INCREASE NETWORK RESOURCES ASSIGNED TO CLIENT AND SERVICE OF SELECTED GOAL — 418

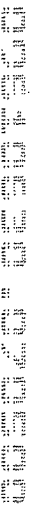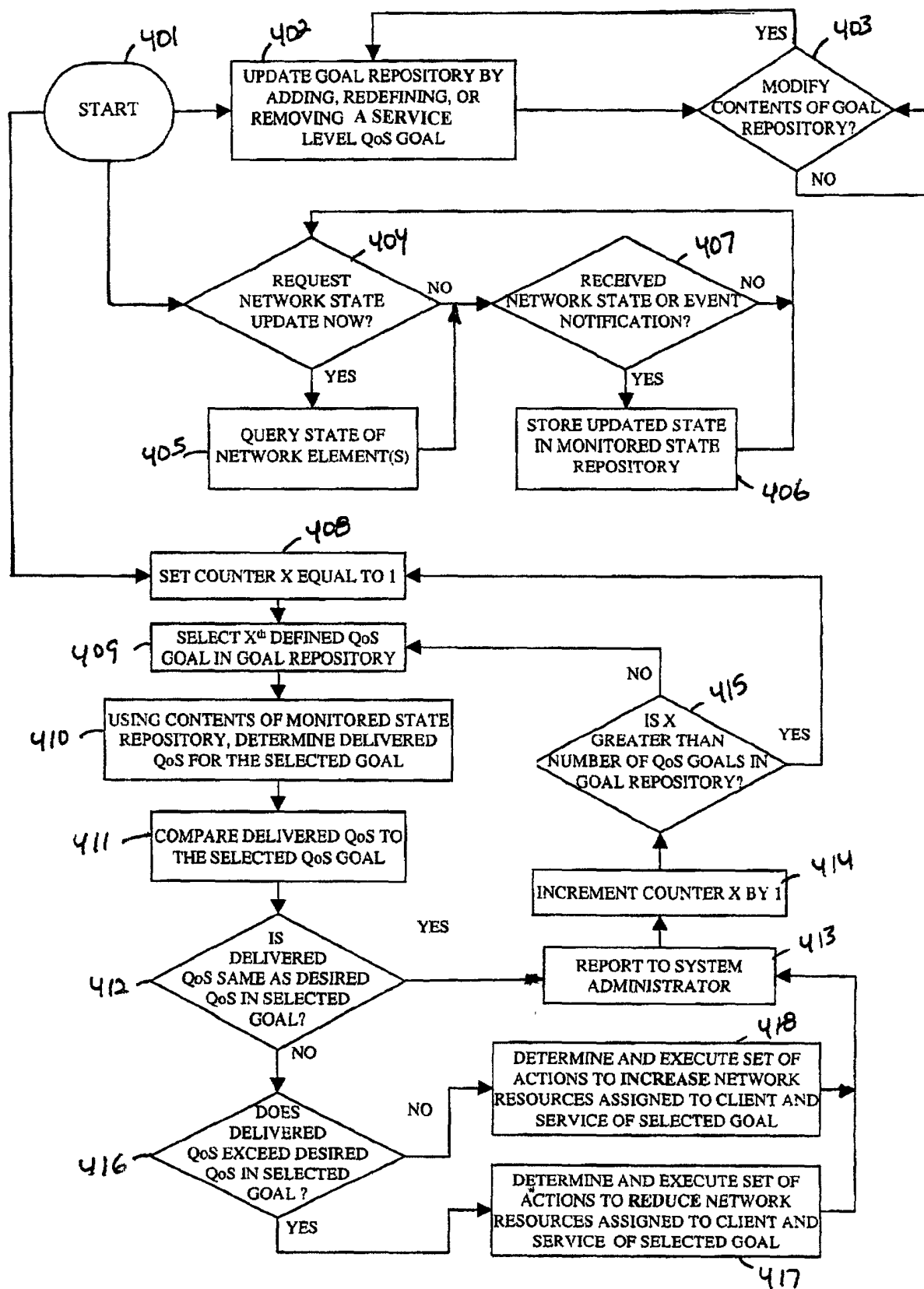DETERMINE AND EXECUTE SET OF ACTIONS TO REDUCE NETWORK RESOURCES ASSIGNED TO CLIENT AND SERVICE OF SELECTED GOAL — 417

IN THE UNITED STATES
PATENT AND TRADEMARK OFFICE

Declaration and Power of Attorney

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **METHOD AND APPARATUS FOR USE IN SPECIFYING AND INSURING SERVICE-LEVEL QUALITY OF SERVICE IN COMPUTER NETWORKS** the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by an amendment, if any, specifically referred to in this oath or declaration.

I acknowledge the duty to disclose all information known to me which is material to patentability as defined in Title 37, Code of Federal Regulations, 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

None

I hereby claim the benefit under Title 35, United States Code, 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

None

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint the following attorney(s) with full power of substitution and revocation, to prosecute said application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent and Trademark Office connected therewith:

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     I hereby appoint the attorney(s) on ATTACHMENT A as associate attorney(s) in the aforementioned application, with full power solely to prosecute said application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent and Trademark Office connected with the prosecution of said application. No other powers are granted to such associate attorney(s) and such associate attorney(s) are specifically denied any power of substitution or revocation.

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